Faster 3D Measurements for Industry - A Spin-off from Space

Carl-Thomas Schneider
AICON 3D Systems GmbH,
Braunschweig, Germany

Joachim Becker
ESA Directorate of Technical and Operational Support,
ESTEC, Noordwijk, The Netherlands

Susanne Marek
ESA Directorate of Industrial Matters and Technology Programmes,
ESTEC, Noordwijk, The Netherlands

Technology R&D for space applications can have an extremely stimulating effect on industrial development in general. Investments in R&D are important for European Industry both to maintain and improve its position in the global marketplace. However, the road from that first idea to an operational prototype is not always easy or without risk. ESA's Technology Transfer Programme therefore helps small and medium-sized enterprises to pursue novel ideas and bring them to market in a timely manner. The ProCam described here is one such example of a space-related development that is helping to improve our daily lives.

Introduction

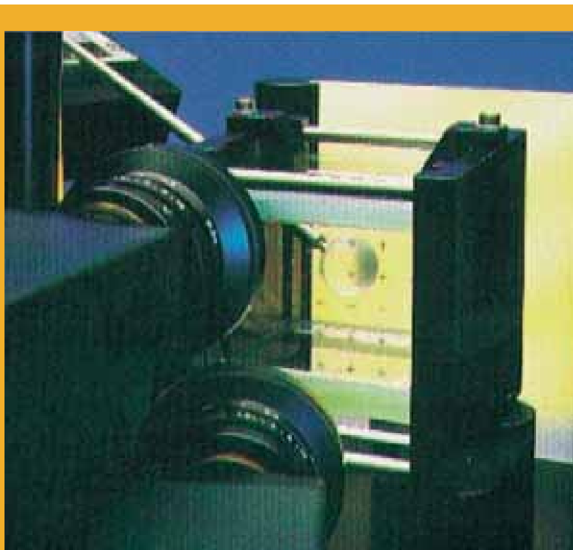
During the late nineteen eighties, in the field of microgravity research in fluid physics, there was a growing demand for non-invasive optical diagnostic tools to detect convective flow patterns, to measure velocity distributions and to determine the behaviour of bubbles in fluids and fluid columns. As such phenomena are usually highly dynamic and three-dimensional, all parameters involved must be measured simultaneously in real time. Moreover, methods that make use of mechanical scanning have an impact on the microgravity environment being measured, and also have limited temporal resolution. In 1991, therefore, ESTEC introduced 'Close Range Photogrammetry' as a non-invasive means of measuring position in three-dimensions and velocities by performing a sequence of measurements as a function of time.

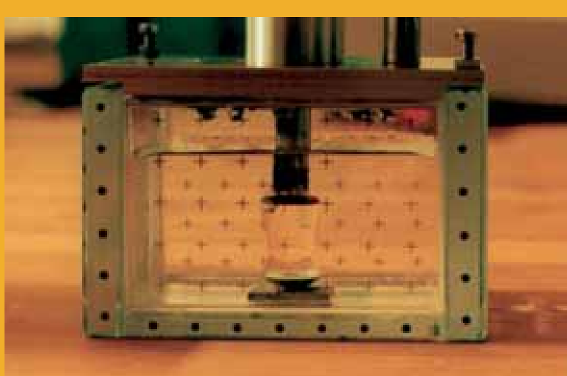
The principle behind such 3D-measurements of position is used subconsciously by most human beings to orientate themselves in their local environment. It requires the two slightly different views from our two eyes and our brain to make good positional 'calculations' within a range of about 25 metres. Larger distances are only estimated by comparing the relative sizes of known objects. The invention of photogrammetry has extended our stereoscopic viewing performance to highly precise measurements by enlarging the number of views and by introducing a calibrated reference space. Spatial resolution to object size ratios of up to 1:100 000 have already been achieved with stationary photogrammetric set-ups and special cameras.

Development for Space

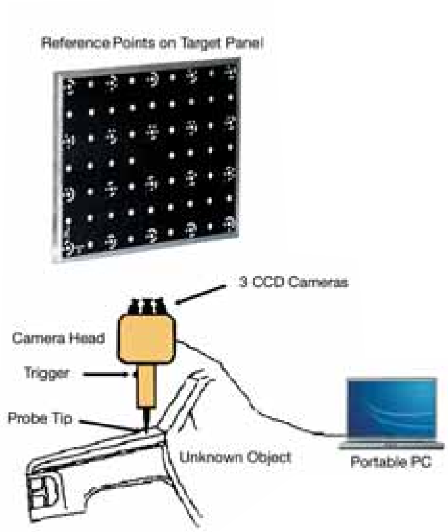
Within the framework of the ESA Technology Research Programme (TRP), the application of photogrammetry for space microgravity experiments (10 x 10 x 10 mm^3 to 100 x 100 x 100 mm^3) has been brought to a considerable level of maturity by miniaturising and generally refining methods already commonly used on the ground for large objects, and by making use of the first CCD (Charge Coupled Device) video cameras that became available at the beginning of the nineties.

A camera head containing three or four small electronic cameras, looking from one main viewing direction, was found to be best suited for making the measurements needed with sufficient accuracy (i.e. ± 0.1mm within a 1 litre volume).





The breadboard of an experiment fluid cell (above), and a fluid experiment cell with Réseau Crosses on its faces



Schematic of the basic elements of the ProCam system

The experiment's calibrated 3D-reference space, a set of Réseau Crosses fixed to the fluid cell's temperature-stable quartz-glass windows, even allowed for relative movements between the camera head and the experiment. This is an essential feature for a modular space multi-user facility with exchangeable experiment containers, where the experiment and the diagnostics cannot be kept fixed and aligned with each other in the way that they can for a stand-alone experiment in a ground-based laboratory. Moreover, it allows measurement accuracies about an order of magnitude better than required (about ± 15 micron within 1 litre).

The first fluid-science experiment making use of photogrammetry was subsequently successfully flown by ESA/ESTEC in 1999 on the Maser-8 sounding-rocket flight.

Extrapolation to Industrial Applications

The mobility achieved with the compromise of sufficient, but not maximum state-of-the-art photogrammetric measurement performance, triggered the idea for the spin-off described here – a comparatively inexpensive, mobile tool for accurate 3D-photogrammetric measurements in industry!

The transportation of equipment in order to coordinate/calibrate different measuring machines is time-consuming and leads to delays and interruptions in production because of the extended set-up times. A mobile 3D-measuring system offers fast and flexible control on the factory floor, avoids expensive production interruptions, and reduces set-up times to minutes. Realising the benefits, therefore, that such mobile 3D-measuring technology could have for industry, ESA's Technology Transfer Programme (TTP) began at the end of 1999 to support the development of a first prototype of the mobile 3D-probe now known as 'ProCam'.

The first-generation ProCam consisted of an active probe with three medium-resolution CCD cameras and a portable PC for system control. It was equipped with a measuring tip to touch object points of interest. During the measurements, the cameras face a field of reference points located on nearby portable or fixed panels (equivalent to the Réseau Crosses on the fluid-cell windows), and the resulting 3D-coordinates are immediately shown on the display. The system proved suitable for general metrology purposes, as well as special applications in niche markets such as car crash-test measurements and examinations of large welded constructions.

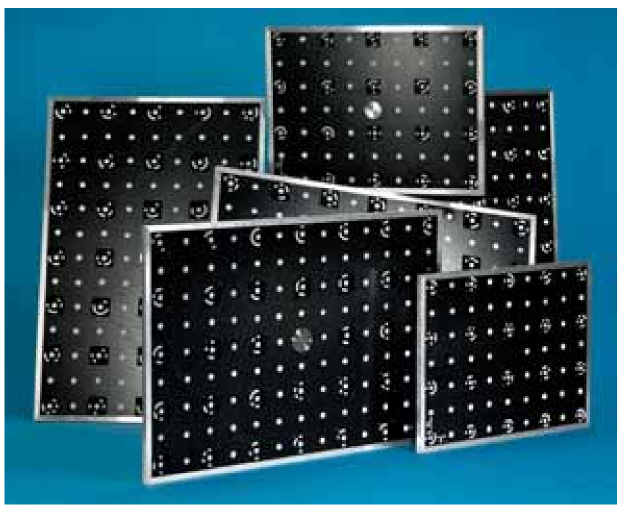
These first successful applications and the experiences of and feedback from pilot users led to the conclusion that, for wider and hence more profitable business applications, some improvements to the first-generation ProCam would have to be made. The hardware components had to be reduced in number and complexity for easier manufacture and lower production costs. Use of off-the-shelf components would also lead to easier maintenance. The software also had to be redesigned to allow even more user-friendly operation. Development therefore continued, supported by the ESA Technology Transfer Programme, to get the second-generation ProCam onto the market.


First-generation ProCam measurement head


Second-generation ProCam for industrial metrology

The probe of the latest ProCam has just one, high-resolution, off-the-shelf CCD camera, which both lowers production costs and simplifies calibration. An integrated infrared flash illuminates the target panels, enabling the system to be operated independently of the ambient light. Also, the probe tips are exchangeable and available in various shapes and lengths, allowing measurements to be made even in the most inaccessible places. The measuring probe is attached with a standard bayonet fixing and no recalibration is needed after exchanging probes.

By using calibrated, transportable, optically coded target panels (600 mm x 800 mm and 800 mm x 1200 mm carbon-fibre plates), it is possible to set up stationary or mobile measurement stations. For stationary operation, the reference targets can also be fixed to the walls and/or ceiling of a measuring room, and the coordinates of the reference points will again be calibrated with high precision. The measuring volume is unrestricted, allowing the ProCam to be applied to objects of any size, with a measuring accuracy of ± 0.1 mm + 0.1 mm/m distance to panel (e.g. distance 1 m, accuracy ± 0.2 mm). This offers sufficiently high accuracy potential for both large and small objects.


Some mobile target panels


Exchangeable ProCam probe tip


Preparing for ProCam measurements on a vehicle to be crash-tested with reference points on the walls of the measurement chamber

Applications and Markets

Aside from the obvious general-purpose metrology system market, other niche markets with very particular requirements, mainly in the fields of automotive and aerospace testing, are also emerging. Measurements on crash-test vehicles and position detection for intelligent sensors during modal-test analyses are just two examples of successful applications of the new-generation ProCam. The experience gained in these and other areas of application shows improved system stability and reliability during operation.

Manufacturing halls are another obvious potential major application for ProCam, as it is easy install several measurement stations in various places and then to use just one mobile probe for all of the measurements, particularly as the system can be ready for operation within a few minutes. Such a mobile application allows fast checks to be made on the factory floor, and the item to be measured no longer has to be transported to a special measurement room. This reduces set-up work and can thus shorten product-development and production start-up times.

More than 15 ProCam systems, costing between 60 000 and 80 000 Euros each, have already been installed in Europe and the United States. The short-term sales target is 20-30 installations worldwide per year and the long-term sales target 50 installations per year. To fulfil the long-term market expectations, a less expensive version of the second-generation ProCam, with a lower accuracy rating for less demanding applications, will be produced. In fact, the ProCam is expected to become AICON's (www.aicon.de) leading product for the next few years.

Outlook

One of the most promising of the niche applications has turned out to be the 3D-position detection of a new generation of intelligent sensors. For enhanced sound and vibration testing and reliable simulations, it is necessary to detect the position and orientation of those sensors with special accuracy. Current tools like rulers and tape measures are no longer accurate enough, but the second-generation ProCam is uniquely equipped for such a task.

A first demonstration in the ESTEC Test Centre quickly demonstrated the key advantages of the ProCam approach and the many benefits of its application in the field of sound and vibration testing, not least the significant reduction in instrumentation time. As the vibration testing of space hardware is almost a daily task at ESTEC, the ProCam promises considerable gains in efficiency and reliability, particularly during intensive testing periods involving large spacecraft and other sizable objects. This type of application could result in major worldwide market opportunities. esa

Benefits for our Daily Lives: The ESA Technology Transfer Programme (TTP)

Over the past 35 years, European space industry has gained considerable expertise in building, launching, controlling and communicating with satellites. From this long experience of how to overcome the hazards and problems created by such a hostile environment, many valuable new technologies, products and procedures have been developed.

In 1990, the European Space Agency launched a Technology Transfer Programme to provide space solutions for non-space markets, open new opportunities for the space industry and increase Europe's overall competitiveness on the global scene.

Objectives of the Technology Transfer Programme:

– Adapting space technologies for terrestrial applications leading to the improvement of our daily lives.
– Maximising ESA's return on investment in space research, thus benefiting ESA's Member States.
– Providing opportunities for researchers to collaborate with other organisations.
– Allowing the possibility for two-way transfer:
  • spin-off from space to non-space sectors, and
  • the natural spin-in of technologies developed in non-space sectors.

The TTP works in several ways:

– The ESA Technology Transfer Programme is carried out by a network of technology brokers across Europe and Canada. Their job is to identify technologies with potential for non-space applications on one side, and on the other side to detect the non-space technology needs. Subsequently they help exploit the technology and provide assistance in the transfer process.
– The TTP cooperates with National Agencies and with European Community Networks such as the Innovation Relay Centers (IRC's).
– ESA TTP's Partnership Concept: The TTP supports projects that adapt space technologies for non-space applications by providing funding, in partnership with others, for feasibility, prototype and pre-market studies.

Results

The Programme has already achieved over 160 transfers or spin-offs from space to non-space sectors. This success is reflected by the fact that, since the start of the Programmme, technology transfer has generated more than 25 million Euros in turnover for European space companies and 300 million Euros for the non-space industries involved. By 2005, a turnover of more than 1 billion Euros is expected. Already 1500 jobs and 25 new companies have been created.

To learn more about ESA's Technology Transfer Programme, please contact:

Pierre Brisson
Head of the Technology Transfer and Promotion Office
ESA/ESTEC, PO Box 299
2200 AG Noordwijk, The Netherlands

Phone: +31 (0) 71 5655052
Fax: +31 (0) 71 5653854
E-mail: Pierre.Brisson@esa.int


www.iac2003.org
54th International
Astronautical Congress
September 29 - October 3, 2003
Bremen, Germany
new.opportunities@space
IAC
2003
bremen